

The CYGNO experiment

ICHEP, Bologna, Italy, July 6-13th, 2022

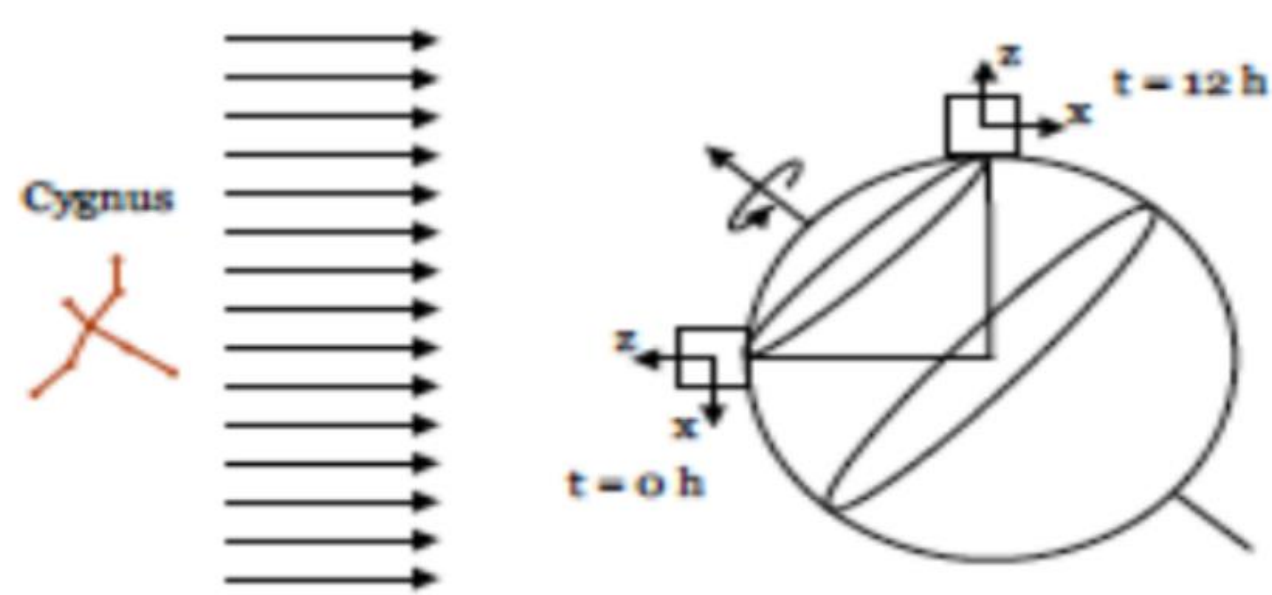
Rita Antonietti, Universita' Roma TRE & INFN, on behalf of the CYGNO Collaboration

F.D.Amaro, R. Antonietti, E.Baracchini, L.Benussi, S.Bianco, C.Capocchia, M.Caponero, D.S.Cardoso, G.Cavoto, A.Cortez, I.A.Costa, R.J.d.C.Roque, E.Dané, G.Dho, F.Di Giambattista, E.Di Marco, G.Grilli di Cortona, G.D'Imperio, F.Iacoangeli, H.P.Lima Júnior, G.S.Pinheiro Lopes, A.d.S.Lopes Júnior, G.Maccarrone, R.D.P.Mano, M.Marafini, R.R.Marcelo Gregorio, D.J.G.Marques, G.Mazzitelli, A.G.McLean, A.Messina, C.M.Bernardes Monteiro, R.A.Nobrega, I.F.Pains, E.Paoletti, L.Passamonti, S.Pelosi, F.Petrucci, S.Piacentini, D.Piccolo, D.Pierluigi, D.Pinci, A.Prajapati, F.Renga, F.Rosatelli, A.Russo, J.M.F.dos Santos, G.Saviano, N.J.C.Spooner, R.Tesauro, S.Tomassini, S.Torelli



Introduction

- Several astrophysical and cosmological observation suggest the existence of cold Dark Matter;
- DM is thought to form an halo through which ordinary, luminous matter in galaxies is travelling in its rotation around the galactic center;
- WIMPs are still one of the most appealing candidates for particle DM; if their mass is around 1-10 GeV/c² they can induce nuclear recoil (NR) of light elements of few keV;
- In its rotation around the Sun, the Earth's orbital velocity is anti-parallel to the DM apparent wind during summer and parallel during winter, the observed DM rates inside the detector are expected to display a seasonal modulation of a few percent;
- Measuring the NR direction allows to measure the DM angular distribution that will show a clear pointing in the direction of the CYGNO constellation, allowing a positive identification of DM a powerful discrimination of neutrinos background.



Optical readout

Charged particles travelling in the gas can ionize and excite atoms and molecules and around 10⁻² – 10⁻¹ photons are emitted per each drifting electron.

Triple Gas Electron Multiplier (GEM) stack to multiply the signal.

3D reconstruction of the tracks thanks to the combined use of:

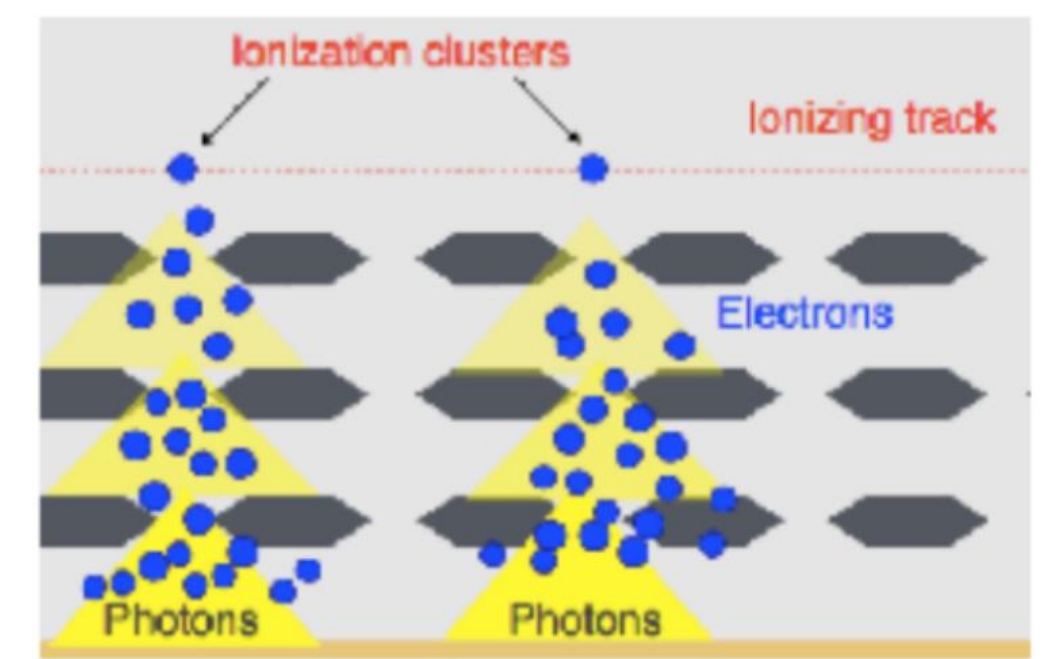
- sCMOS camera
 - Single photon sensitivity;
 - High granularity;
 - for x-y projection;
- PMT
 - Fast light sensor;
 - for z component.



Hamamatsu R7378 PMT



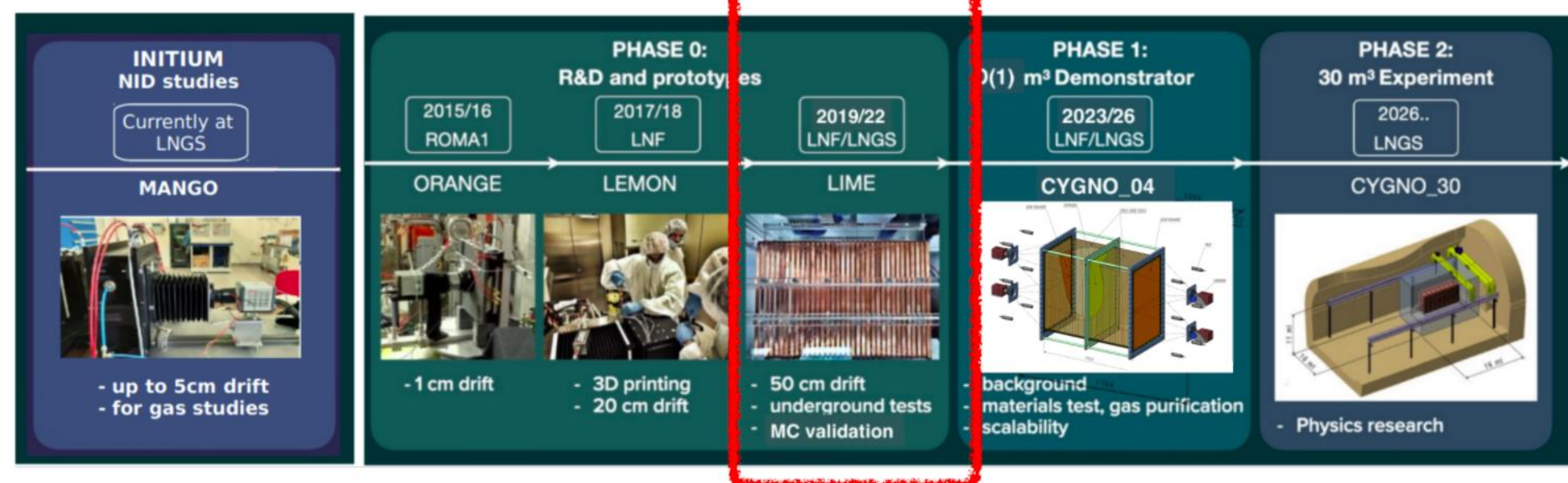
Hamamatsu Orca-Fusion camera



The CYGNO Experiment

The CYGNO experiment [1] goal is to deploy a high-resolution TPC with optical readout at INFN Gran Sasso Laboratories (LNGS) :

- He:CF₄ (60:40) gas mixture at atmospheric pressure and room temperature;
- Triple GEM amplification stage;
- 3D reconstruction of the tracks thanks to the optical readout;
- NR/ER Discrimination capability;



PHASE_0: LIME PROTOTYPE

LIME (Long Imaging Module) is the largest prototype built which is currently installed underground at LNGS:

- 33 x 33 cm² readout area, 50 cm drift distance (50 L volume);
- 4 PMTs;
- 1 sCMOS camera (Hamamatsu ORCA Fusion):
 - 2304 x 2304 pixels;
 - low noise (1 ph/pixel);
 - high granularity.

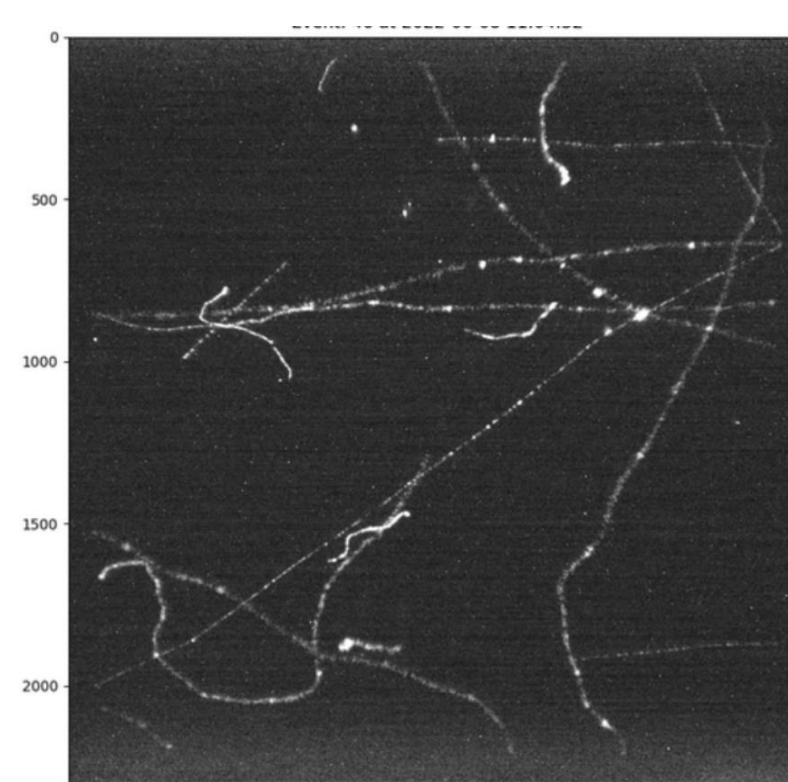
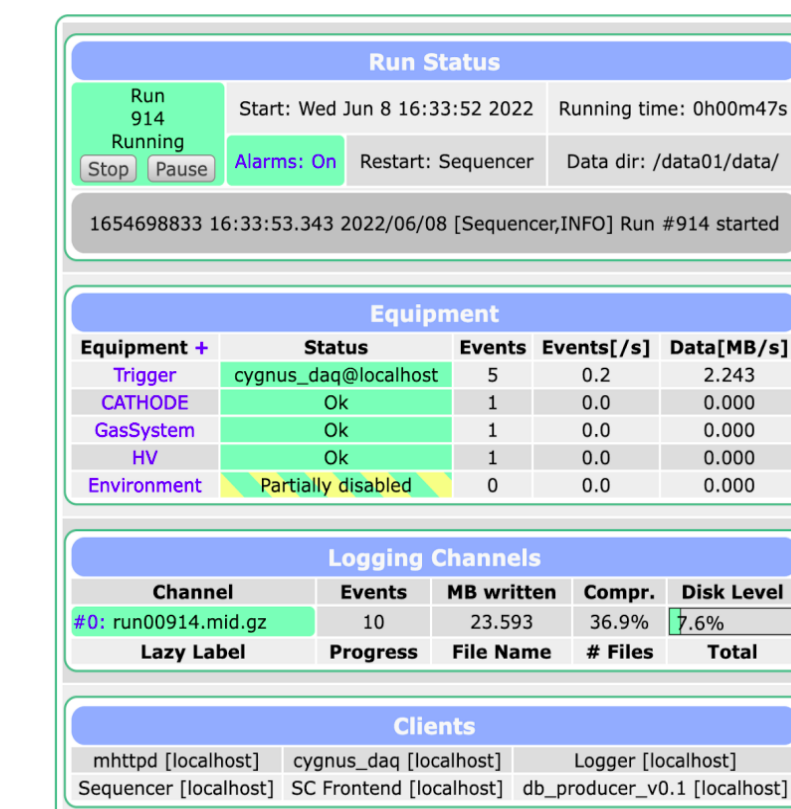
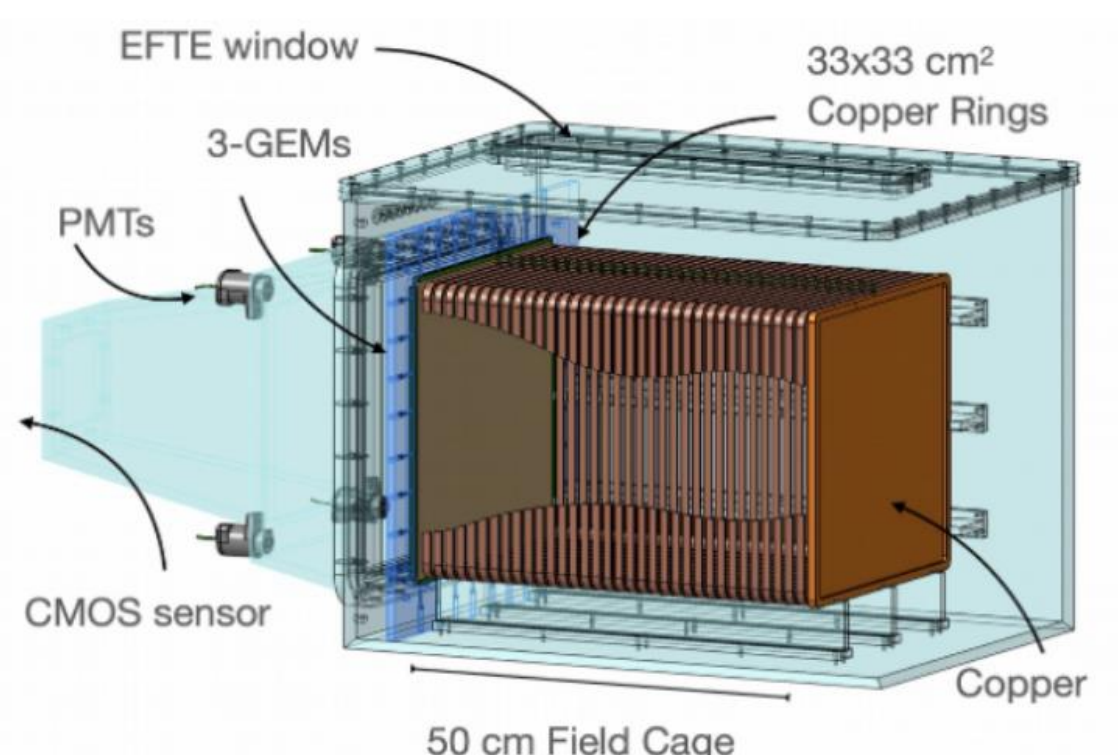


Image taken underground LNGS



Screen shot of the run control panel during data taking



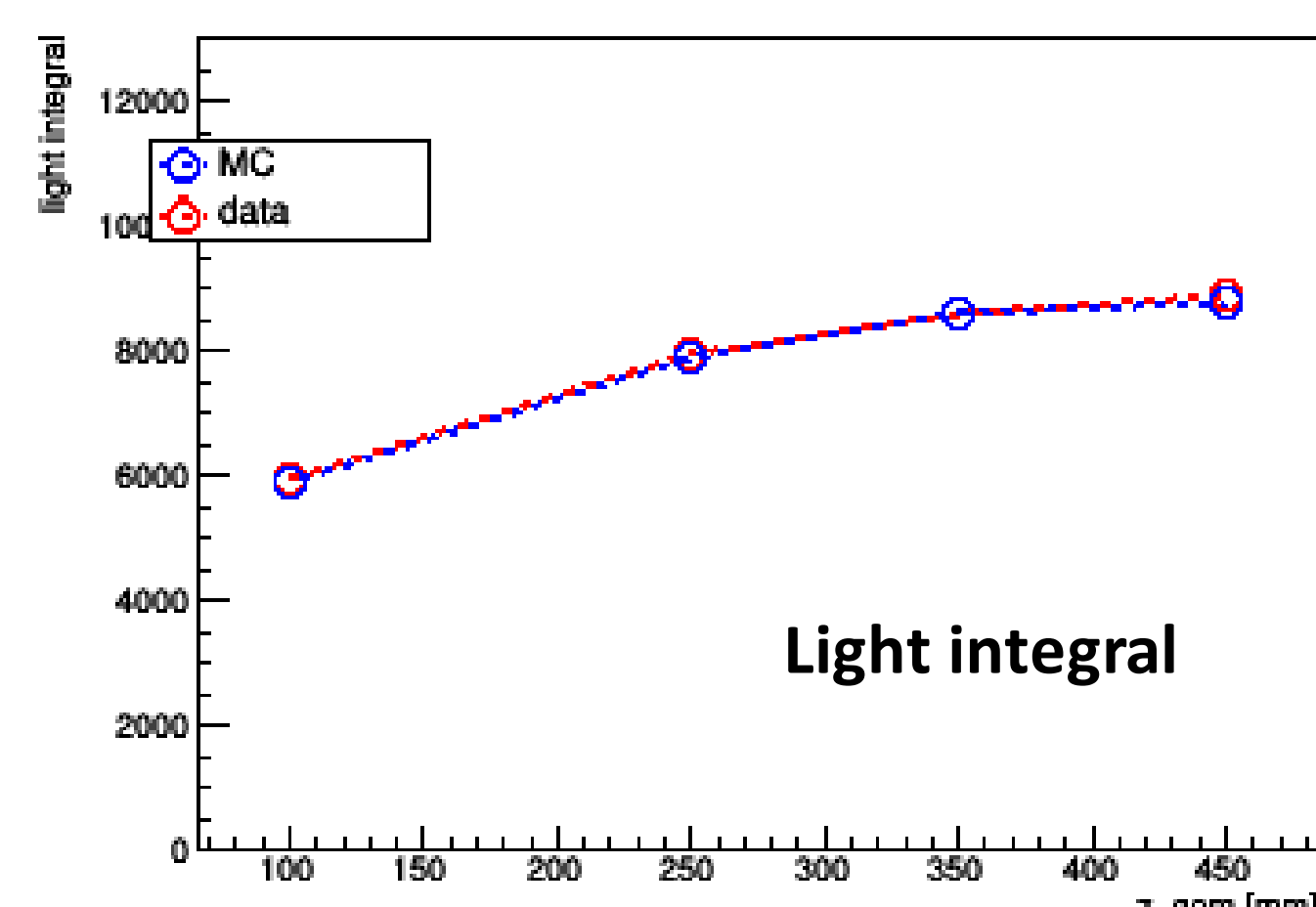
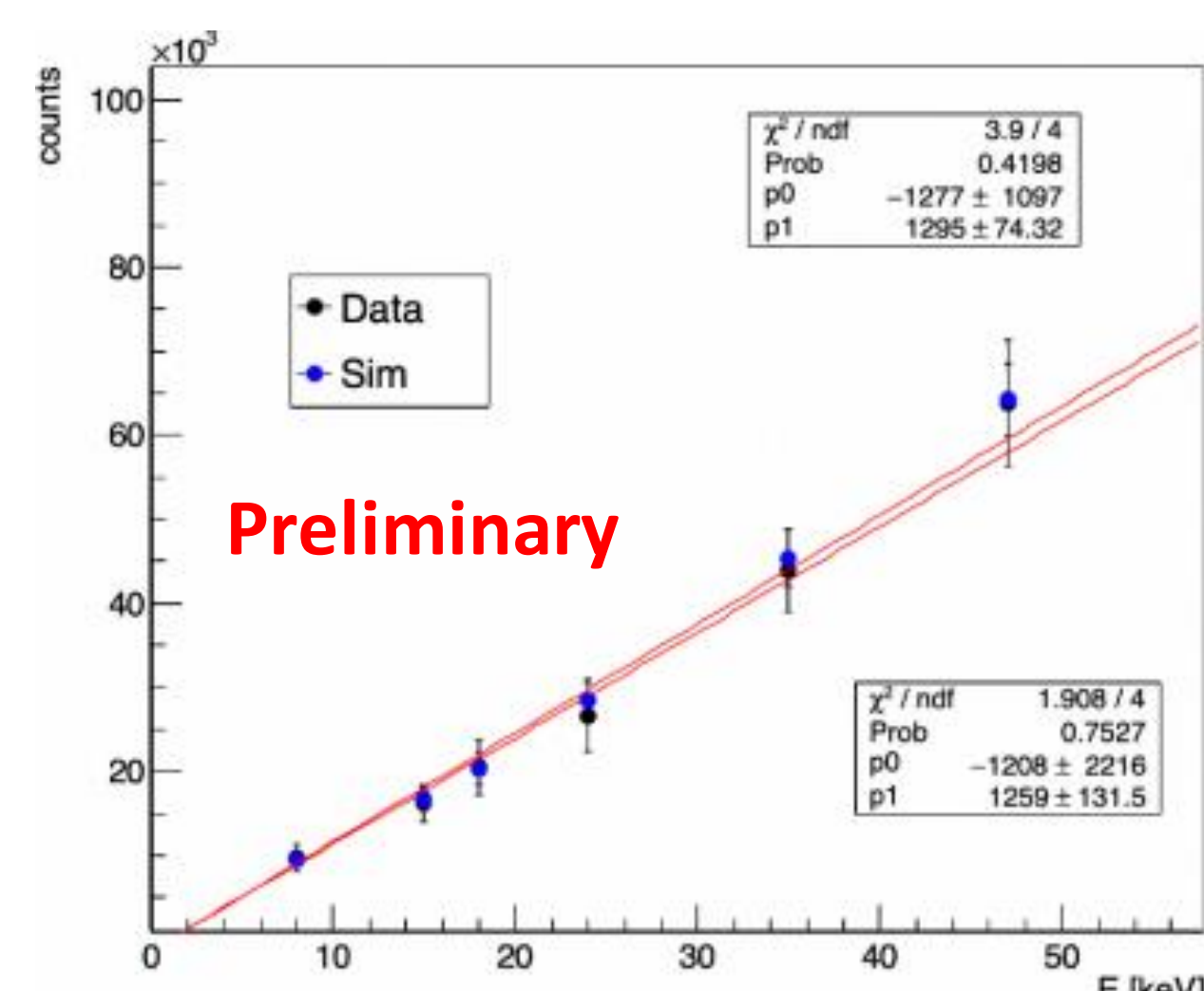
Test with LIME

LIME operated for several months overground at Frascati National Laboratories (LNF – INFN) to study the long term stability and to characterize the prototype with different sources:

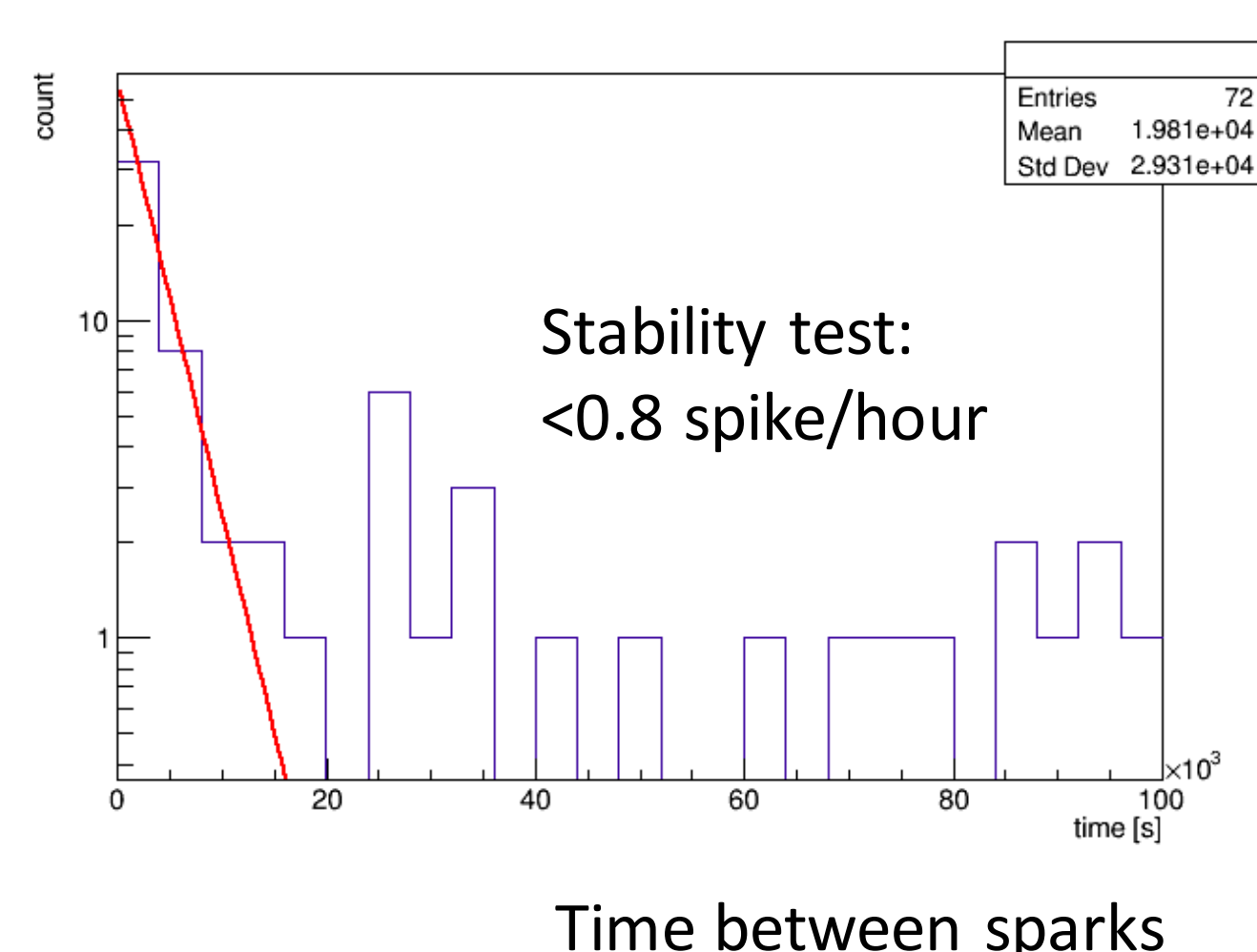
Comparison between data and MC of Multi source of X-ray for energy scan. Reconstruction with a based DBSCAN clustering algorithm [2].

-> **Good linearity**

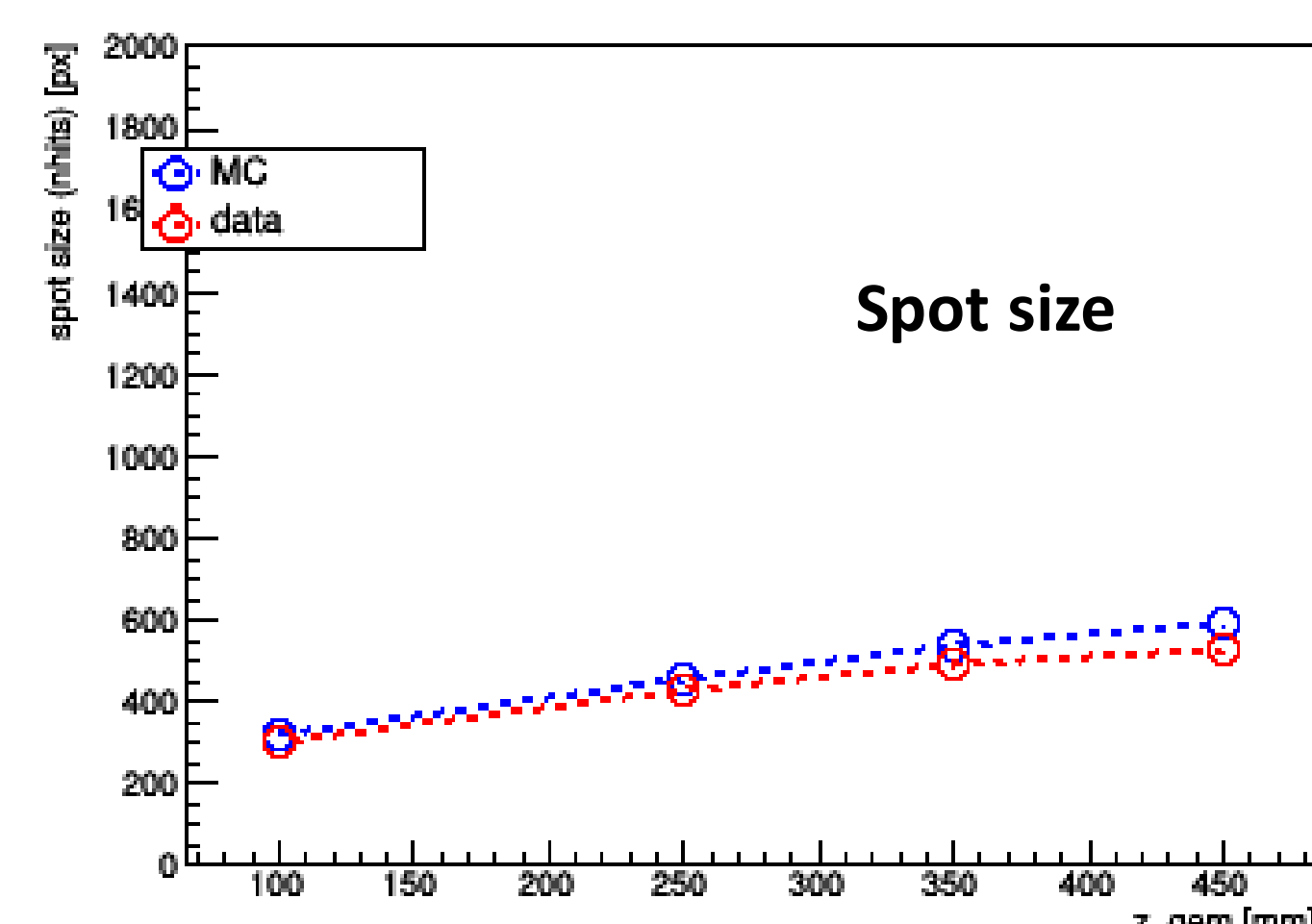
Data-MC comparison using ⁵⁵Fe (5.9 keV) data to study the light integral and the spot size



Light integral



Time between sparks



Spot size

Outlook

Near Future: **CYGNO_04**

Designed Started:

- TPC made of 2 chambers with a common cathode;
- Closed by 2 sets of 50 cm x 80 cm triple GEMs;
- Readout of each GEM side: 2 cameras with rectangular sensors (ORCA Quest) + 6 PMTs;

Background studies:

- Shielding of 100 cm water + 10 cm Cu;
- Relevant background from internal sources;
- Internal NR mostly from GEMs;

Far Future: **CYGNO_30**

It will be able to generate a significant contribution to the search and study of DM in the mass region below 10 GeV

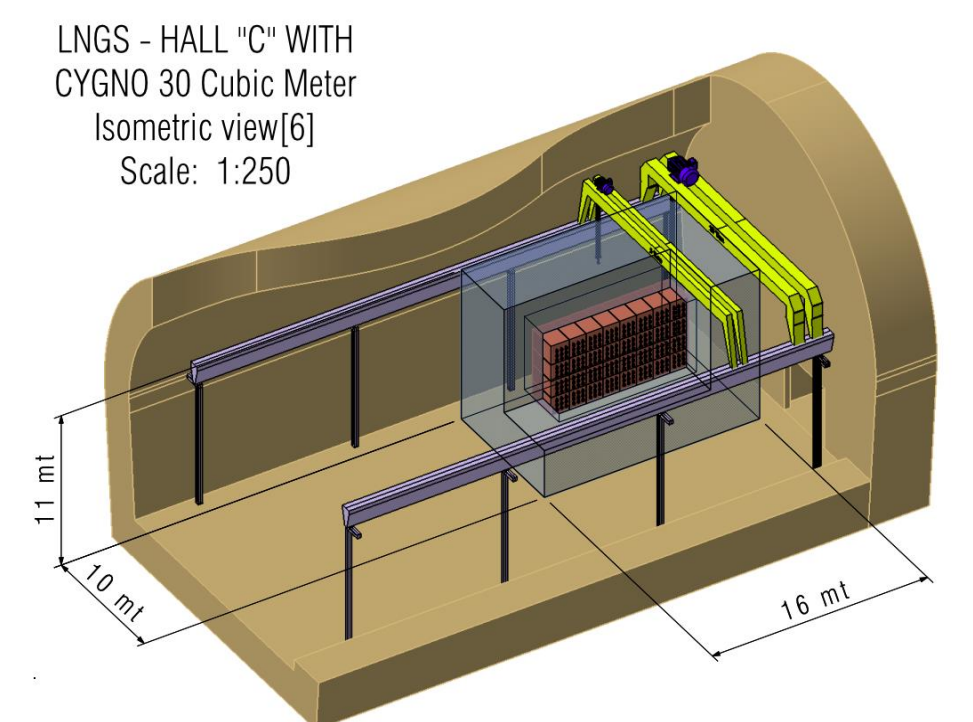
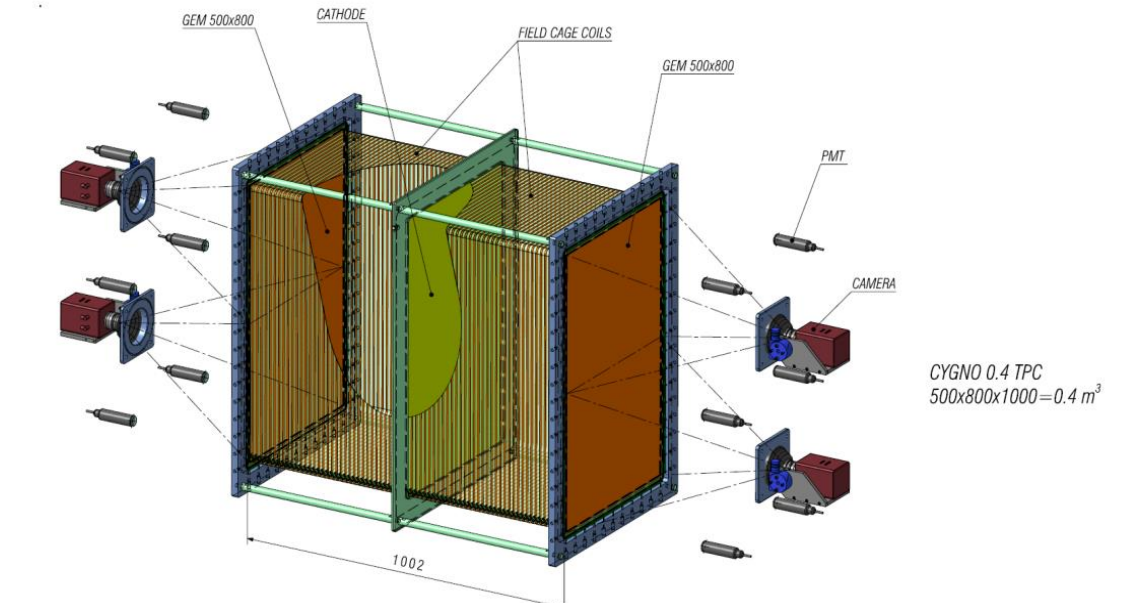
Limits obtained with Bayesian technique

Background characterization and MC validation towards CYGNO_04:

- γ and neutron background at LNGS simulated with GEANT4;
- Neutron flux measurement with full Cu shielding.

Simulated CYGNO_04 background:

- ER rate [1-20] keV = 1.25 x 10⁵ cts/yr;
- NR rate [1-20] keV = 8.64 x 10² cts/yr.



References

- [1] CYGNO Collaboration, Instruments 6(1), 6 (2022)
- [2] E. Baracchini et al., JINST 15 no.12, T12003 (2020)